

## Description

# IMPROVED ELECTRONIC CONTROL FOR RAILWAY AIRBRAKE

### RELATED APPLICATIONS

[0001] This application claims the benefit under 35 U.S.C. 1.19(e) of United States Provisional Application 60/519,391, filed November 12, 2003.

### FIELD OF THE INVENTION

[0002] This invention is related to the railway industry, and in particular, the control of pneumatic brakes for railway vehicles.

### BACKGROUND OF THE INVENTION

[0003] The basic railway triple valve pneumatic airbrake was invented by George Westinghouse over one hundred years ago and the functions of that brake are still in operation today on many railway freight vehicles.

[0004] The basic idea of the triple valve airbrake is to use a pressurized pneumatic line to propagate braking control sig-

nals from the train locomotive to all other vehicles in the train. The pneumatic line, known as the brake pipe (BP), runs the length of the train and is coupled to air reservoirs on each car. The system is charged to an operating state by pressurizing the BP, thus filling the reservoirs on each car with pressurized air. When the air pressure in the BP is allowed to drop, a control valve on each car allows pressurized air to flow from the reservoir into the brake cylinder, thereby providing a mechanical force which applies a brake shoe to the wheel of the railway vehicle. The brake force can be increased until the pressure in the BP and the reservoir are equalized. To release the brakes, pressure in the BP is raised. When the control valve senses the increase, the air is exhausted from the brake cylinders by the valve, and the reservoir is charged until the pressure in the BP and the pressure in the reservoir are equalized.

[0005] The brakes are controlled in the locomotive with two handles, the "independent handle" and the "automatic handle." The independent handle controls the braking of the locomotive, while the automatic handle controls the braking of the entire train, including the locomotive

[0006] The lead locomotive, as well as all other locomotives in the consist, have an independent braking system con-

trolled by the independent handle in the lead locomotive. The independent application and release (IAR) pipe, also known in the railway industry as the "20 pipe," controls the independent brakes in the consist. Therefore, the vehicles in the consist have brake cylinders which can be pressurized by a drop in pressure from the BP or a rise in pressure in the IAR pipe.

[0007] Several improvements to the basic airbrake control have been made since the original design, including the sensing and control of BP and other pipe pressures electronically. One example of such an electronic control for pneumatic airbrakes is the EPIC<sup>®</sup> Electronic Air Brake (EAB) manufactured by Wabtec, Inc. of Wilmerding, Pa. This brake utilizes transducers to sense pressures in the brake pipe (BP), the main reservoir equalizing pipe, the independent application and release (IAR) pipe and the actuating (ACT) pipe, also known in the railway industry as the "13 pipe," which are standard pipes on most locomotive airbrakes, such as the 24RL and the 26L, which operate under the standards of the American Association of Railroads. Additionally, solenoids are used to open and close valves to control the pressures in these pipes. The system is controlled by an on-board computer, which can make

decisions regarding various pipe pressures based on the input of the transducers, the position of the handles in the locomotive and other inputs from other on-board computer systems in the locomotive.

[0008] There have also been attempts to modularize locomotive air brakes. U.S. Patent 5,025,734 (issued 1/25/1991 to Romansky, et al.), entitled "Locomotive Equipment Cage" discloses a system whereby unitized valve assemblies are stacked in a vertical, side-by-side relationship, and are connected to a mating header at one end of the cage.

[0009] Prior art electronic air brake controls are known to have various deficiencies. First, some units in the field are difficult to maintain because of the complexity of the units and the difficulty of replacing parts on the units due to the many electronic and pneumatic connections which must be made. Second, the harsh operating environment of the typical locomotive may include extremes of temperature, vibration and dirt, which can, under some circumstances, be extremely hard on the sensitive computer electronics which control the devices. Therefore, it would be desirable to provide an electronic air brake control unit which has a modular design and field replaceable units which can be quickly and easily swapped in and out in the

field, and further which has improved reliability and redundant computer components.

## **SUMMARY OF INVENTION**

[0010] The air brake of the present invention has an improved physical configuration that allows failed components to be more easily replaced. Components are grouped together into field replaceable units by function. This allows for easy diagnosis of problems and isolation of failed components. The field replaceable units, or "portions," have been designed to allow replacement with a minimum disturbance to the wiring or pneumatic piping of the locomotive into which the brake has been installed.

[0011] All portions of the air brake are connected to a manifold which isolates all pneumatic connections to the locomotive on one side thereof and all replaceable portions on the other side thereof. Channels are defined in the manifold to provide pneumatic air passageways between the locomotive piping and the air handling devices in the portions. As such, replaceable portions can be unbolted from the manifold and replaced very easily, with all pneumatic connections being automatically made when the portion is mechanically attached to the manifold. Additionally, this system allows for customized configurations of the air

brake for individual customers.

[0012] To improve the reliability of the computer components of the airbrake, several improvements have been made over prior art air brake control units. The airbrake now utilizes a distributed and redundant computing topography to ensure reliable operation.

[0013] Each portion of the brake contains a physically identical computing module which has been loaded with software specific to the portion into which it is installed. The software contains instructions for the reading of all transducers within the portion and the control of all solenoids associated with the portion, according to the logic of the software with which it is programmed. Additionally, each computing module contains dual processing units, both of which are independently running the same software and monitoring all transducer outputs. However, only one of the processors is allowed to actuate the solenoids which control the pipe pressures for that portion. The computing modules also contain an independent programmed logic unit which runs an arbitration program to determine which of the processors will be allowed to control the solenoids of that portion.

[0014] The individual computing modules in each portion com-

municate with each other and the outside world via parallel, redundant busses. Some outside inputs are generated by the handles, which are controlled by the engineer, and from the data bus on the locomotive. A gateway is provided between the air brake parallel redundant busses and the locomotive bus to allow the exchange of data therebetween.

#### **BRIEF DESCRIPTION OF THE DRAWINGS**

- [0015] Figure 1a shows the front side of the pneumatic operating unit wherein the field replaceable units are located.
- [0016] Figure 1b shows the reverse side of the pneumatic operating unit where the air handling units are located.
- [0017] Figure 2 shows a schematic diagram of the overall braking system
- [0018] Figure 3a shows a perspective view of the brake handle unit showing the independent and automatic brake handles
- [0019] Figure 3b shows the top view of the brake handle unit of Figure 3a
- [0020] Figure 4 shows a block diagram of the portion controller module.
- [0021] Figure 5 shows a state diagram for the redundancy control circuitry of the portion controller module.

[0022] Figure 6 shows the topology of the distributed control network of the present invention

## **DETAILED DESCRIPTION OF THE INVENTION**

[0023] The air brake control described herein is made up of two major components, handle unit 30 and pneumatic operating unit 10. Handle unit 30 is typically located in the cab of a locomotive and is accessible by the engineer during normal operations. Pneumatic operating unit 10 is typically located in the air brake equipment locker under the cab of the locomotive.

[0024] Handle unit 30 has controls consisting of automatic brake handle 32 and independent brake handle 34. Automatic brake handle 32 controls pressure in the BP, which, in turn, controls the braking of all cars in the train, including locomotives in the train consist. Independent handle 34 controls the pressure in the IAR and ACT pipes, which in turn, controls the braking of the lead locomotive and additional locomotives in the train consist independently from automatic brake handle 32 and the rest of the train.

[0025] The air brake control in a locomotive in a typical train is set up in one of several modes, depending on the configuration of the train. The mode determines which brakes and pipe pressures each locomotive controls and re-



sponds to.

[0026] In a locomotive in LEAD/CUT-IN mode (typically, the first locomotive in the consist) both the automatic handle 32 and the independent handle 34 are active. The air brake accepts input commands from the BP, the IAR pipe, the ACT pipe and various penalty and emergency brake commands originating from both internally (within the air brake control) and externally (i.e., from the locomotive control system). It provides output signals to the air handling devices on the pneumatic manifold to control brake system pressures and accepts feedback from the transducers to provide closed loop control.

[0027] A locomotive in LEAD/CUT-OUT mode (or HELPER mode) has an active independent handle 34, but an inactive automatic handle 32, while a locomotive in TRAIL mode has both independent handle 34 and automatic handle 32 inactive. If configured as LEAD/CUT OUT or TRAIL, the air brake responds to changes in BP pressure commanded by the controlling locomotive.

[0028] Automatic Brake handle 32 normally is designed with at least six positions: RELEASE, MINIMUM SERVICE, FULL SERVICE, SUPPRESSION, CONTINUOUS SERVICE (HANDLE OFF), and EMERGENCY, and is used to control the application

and release of the automatic brake. Each of these positions corresponds to a specific amount of equalizing reservoir pressure reduction. Various degrees of braking are available between minimum service and full service applications.

[0029] The independent brake handle 34 normally has two positions, RELEASE and FULL APPLICATION, with a varying APPLY ZONE therebetween. Each location in the independent brake handle APPLY ZONE corresponds to a specific IAR pipe pressure, and is used to control the application and release of the independent brake.

[0030] The second major component of the air brake system is pneumatic operating unit 10, which consists of pneumatic manifold 12 and the operating portions and various air handling devices.

[0031] Pneumatic manifold 12, shown in Figures 1a and 1b, provides a central unit for the connection and disconnection of the air piping and electrical wiring. This arrangement also provides for easy removal and replacement of air handling devices without having to disturb the locomotive's wiring or piping, thereby making it possible to arrange the portions of the unit in easily field-replaceable units. The use of pneumatic manifold 12 allows the elimi-

nation of much of the external piping associated with the pneumatic brake equipment, a deficiency in many prior art designs. This minimizes the number of locations for leaks to develop and reduces the time for the troubleshooting of any leaks that may develop during the service life of the locomotive.

[0032] One side of pneumatic manifold, shown in Figure 1a contains the connections for the various control portions, namely brake cylinder control portion 14, brake pipe control portion 16 and IAR/ACT pipe control portion 18. The opposite side, shown in Figure 1b, contains connection points for air volumes 23, 24, 25 and 26, which are used to provide stability and appropriate timing response during various operations. Also located on the side of pneumatic manifold shown in Figure 1b are connections to the pneumatic system of the locomotive, including, among others, BP connection 27, IAR pipe connection 28 and ACT pipe connection 29.

[0033] Preferably, manifold 12 is either a laminated assembly or a solid block which has been deep drilled from two or more edges to form the pneumatic air channels within. The preferred metal for manifold 12 is aluminum or an aluminum alloy, but any suitable metal may be used.

[0034] IAR/ACT pipe control portion 18 is connected to manifold 12 as shown in Figure 1a, and is primarily responsible for controlling pressures in the IAR pipe and the ACT pipe, primarily in response to movement of independent handle 34. When independent handle 34 is active, a movement of the independent handle 34 toward the FULL APPLICATION position 42, as shown in Figure 3b, will cause a rise in pressure in the IAR pipe. Brake cylinder pressure in the locomotives in the consist will increase proportionally to increases in pressure in the IAR pipe. A movement of independent handle 34 to the RELEASE position 40 will cause a venting of the IAR pipe and a release of the pressure in the locomotive brake cylinders due to the pressure in the IAR pipe. However, locomotive brake cylinder pressure due to decreases in pressure of the BP are not released from the locomotive brake cylinder. Pressure in the locomotive brake cylinder due to decreased pressure in the BP is released either by restoring pressure in the BO or by pressurizing the ACT pipe. This is accomplished by moving independent handle 34 to the BAIL-OFF position, shown as arrow 44 in Figure 3b.

[0035] Brake cylinder control portion 14 provides the means to control the supply of main reservoir pressure to the brake

cylinders and the exhaust of brake cylinder pressure to the atmosphere for all brake applications and releases. In addition, brake cylinder control portion 14 also provides a pneumatic backup capability to ensure fail safe braking functions in the case of an electronics failure, as well as for a complete loss of electrical power.

[0036] Brake cylinder control portion 14 responds to changes in pressure of the BP to provide automatic brake cylinder pressure, and to changes in the IAR pipe to provide independent brake cylinder pressure. A reduction of BP pressure or an increase in IAR pipe pressure will cause an increase in brake cylinder pressure

[0037] Automatic brake cylinder pressure and independent brake cylinder pressure are released separately, according to the pressures in the BP or the IAR pipe respectively. Brake cylinder control portion 14 can operate in two different modes to release the automatic brake cylinder pressure: direct mode or graduated release mode. In direct mode, an increase in BP pressure of a predetermined amount will cause a complete release of the automatic brake cylinder pressure that had been developed as a result of a reduction of BP pressure. Note that independent brake cylinder pressure in the locomotive developed as a result of a rise

in pressure in the IAR pipe is not released. In graduated release mode, an increase in BP pressure will cause a proportional release of automatic brake cylinder pressure that was developed as a result of the reduction in pressure in the BP. To release independent brake cylinder pressure, independent brake handle 34 is moved to the RELEASE position, which will cause the venting of the IAR pipe and a corresponding venting of independent brake cylinder pressure.

[0038] A bail-off operation, initiated by a movement of independent brake handle 34 to bail off position 44 in Figure 3b will cause all automatic brake cylinder pressure to be released. Bail off is caused by an increase of pressure in the ACT pipe by a predetermined amount.

[0039] Brake pipe control portion 16 provides BP pressure control when the automatic brake is in CUT-IN mode, allows CUT-IN/CUT-OUT configuration of the automatic brake, and provides the means to initiate an emergency vent of BP pressure. In LEAD/CUT-IN mode, the BP pressure follows the pressure in the equalizing reservoir, therefore, BP control portion 16 controls the BP pressure by controlling the pressure in the equalizing reservoir in response to changes in the position of automatic brake handle 32, de-

pending upon the configuration of the locomotive. In TRAIL and LEAD/CUT-OUT configurations, the BP ignores the equalizing reservoir and is controlled by another unit. In TRAIL configuration, the equalizing reservoir pressure is reduced to zero.

[0040] In LEAD/CUT-IN and LEAD/CUT-OUT configuration, the equalizing reservoir pressure is controlled as follows. When automatic brake handle 32 is in the RELEASE position, the equalizing reservoir pressure is increased to a predetermined set point. In the MINIMUM SERVICE position, the equalizing reservoir pressure is decreased by a predetermined fixed amount. In the SERVICE ZONE, the equalizing reservoir pressure is adjusted proportional to the handle position within the service zone. In HANDLE OFF position, the equalizing reservoir is reduced to zero pressure at the normal service rate. Finally, in EMERGENCY position, the equalizing pressure is reduced to zero at the emergency rate.

[0041] Independent application and release portion 18, brake cylinder control portion 14 and brake pipe control portion 16 preferably consist of an aluminum, corrosion resistant treated body, which has been machined to contain the microcontroller module 60, transducers, magnet valves,

valve bushings, check valves, mounting stud holes, air passages and chokes, and electrical connections required for operation. These units are field replaceable. To replace the unit, electrical connection 21 is disconnected and the unit is unbolted from manifold 12. The replacement unit is then bolted onto manifold 12 and electrical connection 21 is re-connected. All pneumatic connections are made automatically when the unit is connected to manifold 12.

[0042] Each of the independent application and release portion 18, brake cylinder control portion 14 and brake pipe control portion 16 are equipped with a portion microcontroller module 60, shown in block diagram form in Figure 4, which controls the functioning of the respective portions, based on portion-specific software contained in on-board memory, such as, for example, FLASH memory. Other than the programming, portion control modules 60 are preferably physically identical for each of portions 14, 16 and 18.

[0043] The portion microcontroller 60 consists of two separate and identical microprocessor circuits, a primary 62 and a secondary 63. Both microprocessors 62 and 63 communicate a periodic watchdog signal and a fault signal to redundancy control circuitry 64. If an electrical or software



malfunction occurs in primary microprocessor circuit 62, redundancy control circuitry 64 is able to switch on-the-fly to secondary microprocessor circuit 63, thereby allowing the brake system to continue operation without interruption.

[0044] The portion microcontroller modules 60 can take input from several sources. Each microcontroller 60 can have pressure transducer inputs 66 which are used to sense pressures in various areas of the braking system, according to the function of the portion being controlled. Additionally, each portion microcontroller 60 can have bi-directional digital I/O ports 68. Currently, the digital I/O ports are used for backup in the case where the supervisor computer on the locomotive fails, and are connected to various mechanical switches in the system that may indicate required actions. As an example, brake pipe control portion 14 has a digital I/O connected directly to automatic brake handle 32 to detect when this handle is moved to the EMERGENCY position. Not all digital I/Os need be used and some may be reserved for future expansion.

[0045] Portion microcontroller 60 also receives input from two, parallel, independent controller area network (CAN)

busses 70 and 72 via CAN transceivers 67 and 68. Inputs received over the CAN networks 70 and 72 include data regarding the positions of braking handles 32 and 34 and signals from a separate CAN used by the locomotive electronics. Both primary microprocessor 62 and secondary microprocessor 63 accept all inputs and can run the same software.

[0046] Each portion microcontroller 60 is also equipped with drivers for solenoid valves 74. The drivers accept signals from the redundancy control circuitry 64 to energize and de-energize the solenoid valves. Solenoid valve drivers 74 also provide feedback signals that allow microprocessors 62 and 63 to determine whether drivers 74 are operating properly.

[0047] The communications between the portion controller 60 and the supervisory processor 90 on the locomotive can use the Controller Area Network (CAN) Bus specification. Both of the redundant microprocessor circuits 62 and 63 use a separate CAN bus 70 and 72 respectively between each of the other portion microcontrollers 60, the independent brake handle 34, the automatic brake handle 32 and supervisory processor 90. A gateway between the portion microcontroller CANs 70 and 72 and the loco-

tive CAN 92 is also provided, and may be conveniently located in brake handle unit 30, although the gateway circuitry may be located anywhere

[0048] The power source for the portion microcontroller 60 is, in the preferred embodiment, 24V DC, and is supplied by power supply 20. An isolated DC/DC converter is used to supply the logic and analog power for the on-board electronics.

[0049] All software in portion microcontrollers 60 preferably resides in on-board memory, preferably FLASH memory, and can be programmable in-circuit. In the preferred embodiment, to reduce the complexity of the PCB circuitry and to enhance reliability, a microprocessor with internal FLASH and RAM memory is used.

[0050] A common board assembly is used for the portion microcontroller 60 on all three portions 14, 16 and 18. The identity of the portion microcontroller 60 is configured by a unique arrangement of jumpers installed on a connector that remains with the portion wiring harness.

[0051] As previously discussed, each portion microcontroller 60 consists of two separate and identical microprocessor circuits, primary 62 and secondary 63. Each microprocessor 62 and 63 communicates with supervisory processor 90

using its own separate CAN network 70 and 72 respectively, and receives power on an independent power bus 20.

[0052] The state diagram for redundancy control circuitry 64 is shown in Figure 5. Each microprocessor 62 and 63 generates a watchdog signal which is periodically transmitted to redundancy control circuitry 64. Additionally, each microprocessor 62 and 63 also can send a fault signal to redundancy control circuitry 64. Under normal circumstances the redundancy control circuitry will be in state 80 as shown in Figure 5, in which primary microprocessor 62 is enabled and is therefore controlling solenoid valves 75 through solenoid valve driver 74. To be in state 80 it is necessary that the watchdog for the primary supervisory circuit 62 be running. Control is switched to state 82, in which secondary microprocessor 63 is enabled under one of two circumstances. If the watchdog signal for primary microprocessor 62 ceases to be received by redundancy control circuit 62 and the watchdog signal from secondary microprocessor 63 is being received, control will pass through state 84 and move to a state 82, regardless of faults present in either microprocessor. In the event that a fault occurs in the primary microprocessor 62, control will

switch to state 82. In the event that both primary 62 and secondary 63 microprocessors are exhibiting faults, control will revert to state 80, which is the primary microprocessor 62. In the event that redundancy control circuit 64 detects that neither primary 62 nor secondary 63 microprocessors are providing a watchdog signal, the system will revert to state 84, in which case shutdown can be initiated, resulting in a brake application.

[0053] The air brake control of the present invention also employs a fail-safe braking feature that provides back-up protection and braking in situations involving total loss of electrical power, computer shutdown, or for when the locomotive is being hauled DEAD-IN-CONSIST/DEAD-IN-TRAIN. Pneumatic backup control valve 22 is a spring and diaphragm operating triple valve, initially charged by pressure from the BP. In the event of a power outage, a normally closed solenoid in the brake cylinder control portion 14 opens, allowing pressure from pneumatic backup control valve 22 to enter the brake cylinders

[0054] A locomotive air brake control system has been described which is an improvement over electronic and mechanical control systems of the prior art. In the present invention,

major portions of the brake control are packaged together in field replaceable units wherein each of the units is able to be easily removed and replaced by bolting the unit to a pneumatic manifold and engaging a single electrical connector. The action of bolting the unit to the pneumatic manifold automatically makes all of the pneumatic connections and therefore voids having to un-secure and re-secure several pneumatic lines. The only other connection that needs to be made to the field replaceable portion is an electrical connection containing power and network connections. Additionally, each of the replaceable portions has a onboard microcontroller which is specific to that portion. This is in contrast to prior art designs which employed one processor to run all functions of the brake, therefore having a single point of failure. The present invention distributes the processing over the portions and, in addition, provides for redundant processing and redundant communications buses. In addition, the configuration of the brake control with the field replaceable units allows customized configurations for varying applications. For example, certain custom applications may only require one of the portions with the functions of the other portions being provided by systems external to the present

air brake control.

[0055] The automatic electric air brake control of the present invention has been described which includes features for improved reliability and maintainability of the unit. The scope of the invention should not be limited by any descriptions of functionality or configuration herein but are embodied in the claims which follow